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(54) Air intake control system for engine equipped with exhaust gas recirculation feature

Saugluftsteuerungssystem für eine Brennkraftmaschine mit Abgasrückführungsvorrichtung

Système de commande d'air d'admission pour moteur à combustion avec dispositif de recirculation des gaz d'échappement

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- **PATENT ABSTRACTS OF JAPAN vol. 1995, no. 02, 31 March 1995 (1995-03-31) & JP 06 330821 A (FUJI HEAVY IND LTD), 29 November 1994 (1994-11-29)**

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Description

[0001] The invention relates to an air intake control system for an engine equipped with an exhaust gas recirculation system which controls the amount of exhaust gas that is recirculated on the basis of a comparison of an air charging ratio with a target charging ratio.

[0002] In order to lower nitrogen oxide (NOx) emissions in the exhaust gas from an engine, it is typical to equip an exhaust gas recirculation system which has exhaust gas recirculation adjusting means and control means for determining a target amount of fresh air charge according to an operated position of an accelerator and an air charging ratio dictated by pressure in an intake air passage and a temperature of intake air and controlling the exhaust gas recirculation adjusting means to remove a difference between a practical amount of fresh air charge detected by an air flow sensor and a target amount of fresh air charge. Such a control system is known from, for example, Japanese Patent Publication No.63 - 5O544. This control system can be applied to gasoline engines as well as to diesel engines. In a fuel direct injection type of gasoline engine adapted to make fuel injection in a compression stroke to form uneven distribution of an air-fuel mixture around a spark plug so as thereby to cause stratified charge combustion, it is potentially performed to recirculate a large amount of exhaust gas into the engine

while stratified charge combustion occurs. In this case, the prior art control system to adjust amounts of fresh air charge and exhaust gas recirculation is effective.

[0003] Another control system is known from, for example, European Patent Application EP 0 752 523. The control system includes an exhaust gas recirculation valve for regulating the amount of exhaust gas admitted to the engine and a throttle valve in an intake passage for controlling the amount of air charge towards a target amount and controls them to decrease detrimental compositions of exhaust gas by applying an appropriate amount of oxygen for fuel burning. In the control system, a target throttle opening is determined on the basis of an amount of fuel injection and an outside air temperature, and a target EGR valve opening is determined on the basis of a recirculated exhaust gas temperature and a temperature of engine cooling water.

[0004] However, the prior art control system is accompanied by aggravation of controllability of the amount of exhaust gas admitted to the engine in the event of, for example, an occurrence of a change in intake air density due to changes in atmospheric pressure and/or temperature. A reduction in intake air density caused due to a change in atmospheric pressure and temperature is accompanied by a reduction in mass of intake air if an engine operating condition and/or recirculation of exhaust gas remain unchanged. In the case where the control of exhaust gas recirculation is performed on the basis of a comparison between a practical amount of fresh air charge and a target amount of fresh air charge, if a correction is made by tempering an amount of fresh air charge with intake air density, the exhaust gas recirculation adjusting means can be controlled to make up a downward tendency of intake air due to a decline in intake air density, which is however accompanied by a reduction in exhaust gas that is recirculated. on the other hand, a rise in intake air density is accompanied by an increase in exhaust gas that is recirculated. In view of the above, therefore, there is aggravation of the control of Nox emissions and the stability of combustion.

[0005] It is an objective of the invention to provide an air intake control system for an automobile engine which appropriately controls both amounts of fresh intake air and exhaust gas admitted to the engine even upon an occurrence of a change in intake air density and desirably controls NOx emissions.

[0006] The foregoing object of the present invention is achieved by an intake air control system for an engine equipped with an exhaust gas recirculation system that comprises engine operating condition detecting means for detecting engine operating conditions including at least an engine speed, an throttle valve opening, an intake air temperature, an amount of intake air, an accelerator opening and atmospheric pressure, target throttle valve opening determining means for determining a target throttle valve opening of a throttle valve according to the detected engine operating condition, target EGR valve opening determining means for determining a target EGR valve opening according to the detected engine operating condition, and control means for controlling variable air intake means including a throttle valve towards die target valve opening. The target throttle valve opening determining means calculates a target engine output torque from the detected engine speed and the detected accelerator opening, determines a basic throttle valve opening according to the detected engine speed and the target engine output torque from a map that defines basic throttle valve openings with respect to engine speeds and target engine output torque, determines an estimated amount of air charge for calculation of a target throttle valve opening from volumetric efficiency that is determined according to the detected engine speed and the detected throttle valve opening from a map in which volumetric efficiency are defined with respect to engine speeds and throttle valve openings and then corrected according to the detected intake air temperature and said detected atmospheric pressure, determines the target amount of air charge according to the detected engine speed and the target engine output torque from a map in which target amounts of air charge are defined with respect to engine speeds and target engine output torque, and calculating the target throttle valve opening from a feedback correction value that is determined according to the target amount of air charge and the basic throttle valve opening and a difference between the estimated amount of air charge. The correction of volumetric efficiency has the tendency to decrease the estimated amount of air charge relative to the target amount of air charge for calculation of a target throttle valve opening as the intake air temperature drops. The target EGR valve opening determining means determines a basic EGR valve opening according to the detected engine speed and the target engine output torque from a map in which basic EGR valve openings are defined with respect to engine speeds and target engine output torque, determines a target amount of air charge for calculation of an EGR valve opening according to the detected engine speed and the target engine output torque from a map in which target amounts of air charge are defined with respect to engine speeds and target engine output torque, and calculates the target EGR valve opening from the basic EGR valve opening and a feedback correction value that is determined according to a difference between the target amount of air charge and an amount of air charge calculated from the detected amount of intake air.

[0007] With the air intake control system, it is realized to control a change in EGR valve opening due to a drop in intake air density following an increase in intake air temperature by correcting a target throttle valve opening for prevention of expansion of a difference between an estimated amount of air charge for calculation of a target throttle valve opening and a target amount of air charge for calculation of a target throttle valve opening that is caused following a temperature rise of engine cooling water. In consequence, the control of exhaust gas recirculation is performed with high accuracy. A marked effect of controlling a change in EGR valve opening takes place especially in a stratified charge combustion mode in which a large amount of exhaust gas is recirculated.

[0008] With the air intake control system, even in the event where intake there occurs a downward tendency of intake air due to a decline in intake air density due to changes in atmospheric pressure and/or temperature, the variable air intake means is controlled to appropriately regulate the practical amount of intake air without an effect of affecting the control of exhaust gas recirculation through the exhaust gas regulating means, as a result of which, an appropriate amount of exhaust gas is admitted to the engine.

[0009] The control of a practical amount of air charge by the variable air intake means may be performed while the exhaust gas recirculation system controls the exhaust gas regulating means. The air intake control system determines a basic throttle valve opening for the electrically actuated throttle valve according to engine operating conditions and corrects a practical throttle valve opening on the basis of the basic throttle valve opening and a difference between the estimated amount of air charge and the target amount of air charge. In this way, in the event of an occurrence of a downward or upward tendency of intake air due to a decline in intake air density, an opening of the throttle valve is corrected to adjust a practical amount of air charge.

[0010] The amount of air charge may be estimated on the basis of an engine speed and a throttle valve opening correctively tempered with intake air density according to a temperature of intake air and the atmospheric pressure, which is always desirable for the variable air intake means, i e. the electrically actuated throttle valve, to perform more precise regulation of a practical amount of air charge in spite of a change in intake air density.

[0011] The basic throttle valve opening and an controlled amount of the exhaust gas regulating means may be determined so that pressure in the intake air passage downstream from the electrically actuated throttle valve is made approximately equal to the atmospheric pressure in an extent of basic throttle openings less than its full position in an engine operating zone in which the control of exhaust gas regulating means and the control of the variable air intake means are performed. In this instance, the basic throttle valve opening is always less than the full position even when the practical amount of air charge is increased, the throttle valve is appropriately controlled to increasingly change its opening according to a decline in intake air density if intake air density declines.

[0012] It is desirable to change a throttle valve opening to a full position only when intake air density is low in an engine operating zone in which the control of exhaust gas regulating means and the control of the variable air intake means are performed and the basic throttle valve opening is changed larger. This makes the throttle valve open to its full position in the state of lower intake air density and causes it to decrease its opening with a rise in intake air density. In this way, the throttle valve changes its opening according to changes in intake air density.

[0013] The engine may be of a fuel direct injection type having a fuel injector which is controlled to inject fuel in a compression stroke to cause stratified charge combustion in a specified engine operating zone. In this type of engine, it is desirable to perform the control of exhaust gas recirculation through the exhaust gas regulating means and the control of intake air through the variable air intake means in at least the specified engine operating zone. In this instance, in the engine operating zone for stratified charge combustion, an airfuel mixture is made lean and exhaust gas is recirculated with an effect of lowering NOx emissions and improving fuel efficiency.

[0014] The foregoing and other objects and features of the present invention will be clearly understood from the following detailed description of preferred embodiments when read in conjunction with the accompanying drawings in which:

Figure 1 is a schematic illustration showing the overall structure of an engine equipped with an air intake control system in accordance with an embodiment of the invention; Figure 2 is a diagrammatic illustration showing engine operating zones for various combustion modes and air-fuel ratios;

Figure 3 is a functional block diagram showing an engine control unit;

Figure 4 is a flow chart illustrating a sequence routine of the exhaust gas recirculation control; and

Figure 5 is a time chart showing changes in various controlled variables.

[0015] Referring to the drawings in detail and, in particular, to Figure 1 schematically showing a multi-eylinder direct fuel injection engine 1O equipped with an exhaust gas recirculation system which is controlled an air intake control system in accordance with an embodiment of the invention, the engine 1O is comprised of a cylinder block la provided with cylinder bores 12 in which pistons 14 slide and a cylinder head lb. A combustion chamber 15 is formed in each eylinder by the top of the piston 14, a lower wall of the cylinder head lb and the cylinder bore 12. An intake port and an exhaust port open into the combustion chamber 15 and are opened and shut at a predetermined timing by an intake valve 17 and an exhaust valve 18, respectively. A spark plug 2O is installed in the eylinder head lb to with its electrode tip placed down into the combustion chamber 15. A fuel injector 22 projects into the combustion chamber 15 from the side and splays fuel directly into the combustion chamber 15.

[0016] Air is introduced into the engine 1 through an intake line 24 including an intake passage 24a which is provided with an air cleaner 25, an air flow sensor 26, throttle valve 28 driven by an electric motor 27 and a surge tank 3O arranged in order from the upstream end. Exhaust gas is discharged into an exhaust line 32 including an exhaust passage 32a from the engine 1. The exhaust line 32 has a catalytic converter 33 disposed in the exhaust passage 32a. An exhaust gas recirculation system 35 is installed between the intake line 24 and the exhaust line 32 to admit an controlled amount of exhaust gas into the intake air stream. The exhaust gas recirculation system 35 incorporates an exhaust gas recirculation valve, such as a vacuum modulated exhaust gas recirculation valve (which is hereafter referred to as an EGR valve) 36, disposed in an exhaust gas recirculation passage 35a connected between the intake passage 24a and the exhaust passage 32a. The EGR valve 36 is actuated by a vacuum actuator 37 cooperating with a vacuum regulator 38 which is comprised of, for example, a pair of duty solenoid valves such as a vacuum induction duty solenoid valve and an atmosphere induction solenoid valve that regulate proportions of a vacuum and the atmosphere, respectively.

[0017] The engine 1 is further provided with various sensors, namely a throttle sensor 41 for detecting a point of throttle opening, a speed sensor 42 for detecting an engine speed, an accelerator position sensor 43 for detecting a position of an accelerator (not shown), temperature sensors 44 and 46 for detecting temperatures of intake air and engine cooling water, respectively, a pressure sensor 45 for detecting the atmospheric pressure, an oxygen (02) sensor 47 for detecting the oxygen concentration of exhaust gas by which an air-fuel ratio is dictated, and a valve position sensor 48 for detecting a point of EGR valve opening. output signals from these sensors 42 - 48 are directed to an engine control unit (ECU) 5O comprised of, for example, a programmed microprocessor and stores various control maps. The engine control unit 5O controls the fuel injector 22, the throttle valve 28 and the EGR valve 36. Specifically, the engine control unit 5O provides control signals, such as a fuel injection control signal with which the fuel injector 22 is actuated to inject a controlled amount of fuel at a controlled timing, a throttle control signal with which the electric motor 27 actuates the throttle valve 28 to open to a controlled point of valve opening and a recirculation control signal with which the vacuum regulator 38 is caused to operate the vacuum actuator 37 so as thereby to control the EGR valve 36 to admit a controlled amount of exhaust gas that is recirculated.

[0018] Figure 2 illustrates engine operating zones for various combustion modes and air-fuel ratios for the direct fuel injection engine. As shown, there are three engine operating zones, namely a stratified charge combustion zone Z1 for lower engine speeds and loading and a homogeneous charge combustion zone for higher engine speeds and loading which is subdivided into two zones, namely a lean homogeneous charge combustion zone Z1 for moderate engine speeds and loading and a stoichiometric homogeneous charge combustion zone Z2 for higher engine speeds and loading. In the stratified charge combustion zone Z1, fuel is sprayed in a later stage of a compression stroke with an effect of uneven distribution of a stratified air-fuel mixture around the spark plug 2O, as a result of which stratified charge combustion is made. In this instance, the throttle valve 28 provides a large throttle opening to admit a large amount of intake air to the engine 1 to make an overall air-fuel mixture significantly lean at, for example, an air-fuel ratio of approximately 4O. In the lean and stoichiometric homogeneous charge combustion zones Z1 and Z2, fuel is sprayed in an early stage of a suction stroke with an effect of homogeneous distribution of an air-fuel mixture in the whole combustion chamber 15. An air-fuel mixture is made leaner (which is otherwise specified by an air excess ratio λ greater than 1) than a stoichiometric air-fuel mixture ($\lambda = 1$) in the lean charge combustion zone Z2, and is maintained stoichiometric in the stoichiometric charge combustion zone Z3.

[0019] Figure 3 is a functional block diagram showing the engine control system 5O.

[0020] As shown, the engine control system 50 determines target engine output torque *Trqob* based on an accelerator position *Acc* detected by the accelerator position sensor 43 and an engine speed *Ne* detected by the speed sensor 42 and an amount of intake air introduced into the engine 1 at function block 52. The determination is made by use of a target torque control map which specifies target engine torque relative to engine speeds and throttle openings. Further, the engine control system 5O determines an amount of air charge *Ce* based on an amount of intake air Afs introduced into the engine 1 which is dictated by an output signal from the air flow sensor 26 at function block 51.

[0021] The engine control system 5O is subdivided into three sections, namely an air charging control section 53, a fuel injection control section 6O and an exhaust gas recirculation control section 65. The air charging control section 53 is comprised of blocks 54 - 57 for determining a basic throttle valve opening *Tvob*, an amount of air charge *Ceco* which is used for a correction of throttle opening, a target amount of air charge *Ceob* and a practical throttle valve opening *Tvo*, and a block 58 for providing a throttle valve control signal *STvo*. At the block 54 a basic throttle valve opening *Tvob* is determined according to an engine operating condition. In the stratified charge combustion zone Z1 and in the lean homogeneous charge combustion zone Z2, basic throttle opening control maps which specify basic throttle openings *Tvob* relative to engine speeds *Ne* and target engine output torque *Trqob* are used. In the stoichiometric homogeneous charge combustion zone Z3 a basic throttle opening *Tvab* is determined to be proportional to an accelerator position *Acc*. In the stratified charge combustion zone Z1, while the basic throttle valve opening *Tvob* is determined to be large sufficiently to make an air-fuel mixture significantly lean, it is fixed at a position, which is less than its full position and in which the pressure of air stream in the intake passage 24a near the engine 1 is approximately equal to or desirably slightly higher than the atmospheric pressure, in spite of changes in engine loading during execution of the exhaust gas recirculation control. However, the basic throttle valve opening *Tvob* may be increased correspondingly to an increase in the amount of exhaust gas recirculation in an engine operating zone in which the basic EGR valve opening (which will be described later) *Pegrb*. At block 55, the air charging control section 53 determines an amount of air charge *Ceest* estimated under the condition that it is granted that no exhaust gas is admitted to the engine 1. The estimation of the amount of air charge *Ceest* (off-EGR air charge) is made by tempering volumetric efficiency dictated by a current engine speed *Ne* and a current throttle valve opening *Tvo* with a corrected intake air density depending upon a temperature of intake air *Tha* and the atmospheric pressure *Atp*. Volumetric efficiency are specified in a map relative to engine speed *Ne* and throttle valve opening *Tvo*. At block S6, the air charging control section 53 finds a target amount of air charge *Ceob* for conditions in which no exhaust gas is admitted to the engine 1. Target amounts of air charge *Ceob* are specified relative to engine speeds *Ne* and target engine output torque *Trqob* in a map. The map specifies amounts of air charge relative to engine speeds and engine output torque which are measured varying throttle valve opening in certain circumstances under interruption of exhaust gas recirculation by a bench test. Further, the air charging control section S3 determines a target throttle valve opening *Tvoob* based on the basic throttle valve opening *Tvob* and a beedback correction amount of air charge *Ctfb* meeting a difference between the target amount of air charge *Ceob* and the estimated amount of air charge *Ceest* at block S7, and provides for a control signal for driving the electric motor 27 to open the throttle valve 28 to the target throttle valve opening *Tvoob* at block 58.

[0022] The fuel injection control section 6O determines a target air-fuel ratio meeting current engine operating conditions at block 61. In this instance, a map for the stratified charge combustion zone Z1 specifies target air-fuel ratios *A*/*Fob* relative to engine speeds *Ne* and target engine output torque *Trqob*, and a map for the lean homogeneous charge combustion zone Z2 specifies target air-fuel ratios *A*/*Fob* relative to engine speeds *Ne* and amounts of air charges *Ce*. However, a target air-fuel ratio *A*/*Fob* is fixed at 14.7 for the stoichiometric homogeneous charge combustion zone Z3.

[0023] The exhaust gas recirculation control section 65 determines a basic EGR valve opening *Pegrb* of the EGR valve 36 according to engine operating conditions and a target amount of air charge *Ceob* during execution of the exhaust gas recirculation control (on-EGR air charge) according to engine operating conditions at blocks 66 and 67, respectively. A map for the stratified charge combustion zone Z1 specifies basic EGR valve openings *Pegrb* relative to engine speeds *Ne* and target engine output torque *Trqob*, and a map for the stoichiometric homogeneous charge combustion zone Z3 specifies basic EGR valve openings *Pegrb* relative to engine speeds *Ne* and amounts of air charge *Ce*. However, the EGR valve 36 is left to remain closed in the lean homogeneous charge combustion zone Z2 because if exhaust gas is recirculated in the lean homogeneous charge combustion zone Z2, there occurs easy aggravation of stable combustibility. Similarly, maps for each of the stratified and stoichiometric homogeneous charge combustion zones Z1 and Z3 specifies target amounts of air charge *Ceob* relative to engine speeds Ne and target engine output torque Trqob. Further, a target EGR valve opening *Pegrob* is determined based on the basic EGR valve opening *Pegrb* and a feedback correction EGR valve opening *Pegrfh* meeting a difference between the target amount of air charge *Ceob* and the amount of air charge *Ce* dictated by an amount of intake air *Afs* detected by the air flow sensor 26 at block 68, and a control signal for driving the vacuum regulator 38 is provided to regulate a vacuum for the actuator 37 so that the EGR valve 36 attains the target EGR valve opening Pegrob at block 69.

[0024] Figure 4 shows a flow chart illustrating a sequence routine of the control of the engine 1 during execution of the exhaust gas recirculation control in the stratified charge combustion zone Z1. CONTROL that is executed in the lean homogeneous charge combustion zone Z2 or in the stoichiometric homogeneous charge combustion zone Z3 or under engine operating conditions that require no exhaust gas recirculation is omitted from the flow chart.

[0025] As shown, when the flow chart logic commences and control proceeds directly to step S1 where various control parameters are detected. Subsequently, after determining a current amount of air charge *Ce* by calculating a function fl of an engine speed Ne and an amount of intake air *Afs* correctively tempered with intake air density according to the temperature of intake air *Tha* and the atmospheric pressure *Atp* at step S2 and a target engine output torque *Trqob* based on the engine speed *Ne* and an accelerator position *Acc* at step S3, a judgement is made at step S4 as to whether the engine operates in the stratified charge combustion zone Z1. When the engine operates in the stratified charge combustion zone Z1, after determining a basic throttle valve opening *Tvob* and an amount of off-EGR air charge *Ceob* both based on the engine speed *Ne* and the target engine output torque *Trqob* at steps SS and S6, respectively, an amount of air charge *Ceest* is estimated by calculating a function f2 of engine speed *Ne* and throttle valve opening *Tvo* correctively tempered with intake air density according to the temperature of intake air *Tha* and the atmospheric pressure *Atp* at step S7. Further, a feedback correction throttle valve opening *Tvofb* is determined by, for example, P-ID control by calculating a function f3 of the target amount of air charge *Ceob* and estimated amount of air charge *Ceest* at step S8. Subsequently, at step S9, a target throttle valve opening *Tvoob* is determined by calculating the following expression:

$$Tvoob = Tvob \times (1 + Tvofb)$$

[0026] Thereafter, a Judgement is made at step S1O as to whether the condition for execution of the exhaust gas recirculation control which includes a specified temperature of engine cooling water is satisfied. When the EGR condition is satisfied, after determining a basic EGR valve opening *Pegrb* and a target amount of on-EGR air charge *Ceob* both based on the engine speed *Ne* and the target engine output torque *Trqob* at steps S11 and S12, respectively, a feedback correction EGR valve opening *Pegrfb* is determined by, for example, PID control by calculating a function f4 of the amount of air charge *Ce* and the target amount of on-EGR air charge *Ceob* at step S13. Subsequently, at step S14, a target EGR valve opening *Pegrob* is determined by calculating the following expression:

$$Pegrob = Pegrb + Pegrfb$$

[0027] Finally, at step S15, the EGR valve 36 is feedback controlled based on the target EGR valve opening *Pegrob* and current EGR valve opening *Pegr*. Specifically, control duty signals *Tegrv* and *Tegra*, which are obtained as functions fS and f6 of target EGR valve opening *Pegrob* and current EGR valve opening *Pegr*, are provided for the vacuum induction duty solenoid valve and the atmosphere induction solenoid valve of the vacuum regulator 38, respectively.

[0028] With the air intake control system in accordance with an embodiment of the invention, in the stratified charge combustion zone Z1, while the throttle valve 28 holds a relatively large opening, fuel is sprayed into the combustion chamber 15 in a later stage of a compression stroke with an effect of uneven distribution of a stratified air-fuel mixture at a proper air-fuel ratio around the spark plug 2O. As a result, the air-fuel mixture is significantly diluted in the entire combustion chamber with ensured combustibility, which is always desirable for fuel economy. Furthermore, a large amount of exhaust gas may be admitted to the engine 1 in the stratified charge combustion zone Z1, as a result of which a significant reduction in NOx emissions is yielded.

[0029] In the event where the engine encounters a change in engine operating condition or in target engine output torque while operating in the stratified charge combustion zone Z1, the parameters such as an amount of air charge, a throttle valve opening *Tvo* and an EGR valve opening *Pegr*vary as shown in Figure 5C - 5F. As shown, when a rise in cooling water temperature *Tha*, which is one of changes in engine operating condition, occurs, while there occurs a tendency toward a decline in the estimated amount of off-EGR air charge *Ceest* with respect to a target amount of air charge *Ceob* due to a drop in intake air density, the tendency is rectified by incorporating a feedback correction of throttle valve opening *Tvofb* meeting the drop in intake air density. A tendency for the amount of on-EGR air charge to decline due to the drop in intake air density is rectified by incorporating a feedback correction of throttle valve opening *Tvofb* and, consequently, an EGR valve opening *Pegr* controlled based on a difference between a target amount of air charge *Ceob* and an amount of on-EGR air charge *Ce* is kept at an approximately fixed point. While, in the prior art intake air control, a tendency for air charge to decline due to a drop in intake air density is accompanied by a reduction in exhaust gas admitted to the engine as a result of execution of the exhaust gas recirculation in response to the decline in air charge, however, the intake air control system of the invention incorporates the feedback correction of throttle valve opening with which the tendency to decline in air charge due to a drop in intake air density is rectified and both amounts of air charge and exhaust gas recirculation are desirably regulated, consequently. In particular, in the stratified charge combustion zone Z1, while a large amount of exhaust gas is admitted to the engine 1, the throttle valve 28 remains opened to a relatively large opening and holds a relatively low vacuum in the intake passage, there occur fluctuations in the amount of exhaust gas admitted to the engine 1 due to changes in intake air density. Nevertheless, since the intake air control system of the invention controls the throttle valve to vary its opening according to changes in intake air density before execution of the exhaust gas recirculation control according to amounts of air charge, the exhaust gas recirculation control is performed with higher precision. Furthermore, while the basic throttle valve opening *Tvob* is set as relatively large as possible but at a point less than a full opening, the amounts of exhaust gas recirculation and air charge are controlled by varying the basic EGR valve opening *Pegrb* and the basic throttle valve opening *Tvob* in response to an occurrence of a change in target engine output torque *Trqob*. That is, when the target engine output torque *Trqob* is risen, while the basic EGR valve opening *Pegrb* is increased to increase the amount of exhaust gas recirculation so as thereby to restrain an increase in NOx emissions, the basic throttle valve opening *Tvob* is increased by a value meeting the increased amount of exhaust gas recirculation and the target amount of off-EGR air charge *Ceob* is increased correspondingly to the increase in basic throttle valve opening *Tvob*. The target EGR valve opening *Pegrob* and the target throttle valve opening *Tvoob* are feedback control to vary following changes in basic EGR valve opening *Pegrb* and basic throttle valve opening *Tvob*. Consequently, when the amount of exhaust gas recirculation is increased as the EGR valve opening *Pegr* increases, the throttle valve opening *Tvo* is increased by the increased exhaust gas recirculation, as a result of which, a proper amount of air charge is fixedly provided.

[0030] As described above, since, while the intake air control system makes both basic EGR valve opening *Pegrb* and basic throttle valve opening *Tvob* larger in the stratified charge combustion zone Z1, the basic throttle valve opening *Tvob* is limited to a point less than full position, it is possible to correct a throttle valve opening *Tvo* toward larger positions upon an occurrence of a drop in intake air density.

[0031] The basic throttle valve opening *Tvob* may be previously determined so that a correction of throttle valve opening brings the throttle valve 28 into full position upon an occurrence of a decrease in intake air density in the stratified charge combustion zone Z1. The motor driven throttle valve 28 as variable air charging means may be substituted by, for example, an idle speed control valve disposed in a passage bypassing the throttle valve 28. Assuming that a certain amount of exhaust gas is admitted in the state wherein the exhaust gas recirculation control according to amounts of air charge is interrupted, an amount of air charge and a target amount of air charge in the state may be obtained in place of the estimated amount of off-EGR air charge *Ceest* and the target amount of off-EGR air charge *Ceob.*

Claims

1. An air intake control system for an engine equipped with an exhaust gas recirculation system (35) for performing control of exhaust gas regulating means (36, 37, 38), said air intake control system comprising engine operating condition detecting means (41, 42, 43, 44, 45, 46) for detecting an engine operating condition including at least an engine speed (Ne), an throttle valve opening (Tvo), an intake air temperature (Tha), an amount of intake air (Afs), an accelerator opening (Acc) and atmospheric pressure (Atp), target throttle valve opening determining means (50, 57) for determining a target valve opening (Tvoob) of a throttle valve (28) according to said engine operating condition, target EGR valve opening determining means (50, 68) for determining a target valve opening (Pegrob) of an EGR valve (36) according to said engine operating condition, and control means (50, 53) for controlling variable air intake means including a throttle valve (27, 28) to control said throttle valve (28) towards said target valve opening (Tvoob)said EGR valve (36) towards said target valve (Pegrob), **characterized in that**:

   said target throttle valve opening determining means (50, 57) performs a calculation of a target engine output torque (Trqob) from said detected engine speed (Ne) and said detected accelerator opening (Acc), determination of a basic throttle valve opening (Tvob) according to said engine speed (Ne) and said target engine output torque (Trqob) from a map defining basic throttle valve openings with respect to engine speeds and target engine output torque, an estimate of an estimated amount of air charge (Ceest) for calculation of a target throttle valve opening from volumetric efficiency that is determined according to said detected engine speed (Ne) and said detected throttle valve opening (Tvo) from a map defining volumetric efficiency with respect to engine speeds and throttle valve openings and then subjected to a correction according to said detected intake air temperature (Tha) and said detected atmospheric pressure (Atp) which has the tendency to decrease said estimated amount of air charge relative to a target amount of air charge (Ceob) for calculation of a target throttle valve opening as said intake air temperature drops, determination of said target amount of air charge (Ceob) according to said detected engine speed (Ne) and said target engine output torque (Trqob) from a map defining target amounts of air charge with respect to engine speed and target engine output torque, and a calculation of said target valve opening (Tvoob) of said throttle valve (28) from a feedback correction value (Ctfb) that is deter-

mined according to a difference between said estimated amount of air charge (Ceest) and said target amount of air charge (Ceob) and said basic throttle valve opening (Tvob); and
said target EGR valve opening determining means (50, 68) performs determination of a basic EGR valve opening (Pegrb) of said EGR valve (36) according to said detected engine speed (Ne) and said target engine output torque (Trqob) from a map defining basic EGR valve openings with respect to engine speeds and target engine output torque, determination of a target amount of air charge (Ceob) for calculation of an EGR valve opening according to said detected engine speed (Ne) and said target engine output torque (Trqob) from a map defining target amounts of air charge with respect to engine speeds and target engine output torque, and a calculation of said target valve opening (Pegrob) of said EGR valve (36) from said basic valve opening (Pegrb) of said EGR valve (36) and a feedback correction value (Pegrfb) that is determined according to a difference between said target amount of air charge (Ceob) and an amount of air charge (Ce) calculated from said detected amount of intake air (Afs).

2. The air intake control system as defined in claim 1, **characterized in that** said control means (50, 53) performs control of said amount of air charge by said variable air intake means (27, 28) while said exhaust gas recirculation system (35) performs said control of said exhaust gas regulating means (36, 37, 38).

3. The air intake control system as defined in claim 1, **characterized in that** said variable air intake means (27, 28) comprises an electrically actuated throttle valve.

4. The air intake control system as defined in claim 1, **characterized in that** said basic throttle valve opening and an controlled amount of said exhaust gas regulating means (36, 37, 38) are set so that pressure in an intake air passage (24a) downstream from said variable air intake means (27, 28) is made approximately equal to the atmospheric pressure in an extent of said basic throttle opening less than said full position in an engine operating zone in which said control of exhaust gas regulating means (36, 37, 38) and said control of said variable air intake means (27, 28) are performed.

5. The air intake control system as defined in claim 1, **characterized in that** said throttle valve opening is set to a full position only when intake air density is low in an engine operating zone in which said control of exhaust gas regulating means (36, 37, 38) and said control of said variable air intake means (27, 28) are performed and said basic throttle valve opening is set to be large.

6. The air intake control system as defined in claim 1, **characterized in that** said engine is of a fuel direct injection type having a fuel injector (22) which is controlled to inject fuel in a compression stroke to create a stratified air-fuel mixture in a specified engine operating zone and said control of exhaust gas recirculation through said exhaust gas regulating means (36, 37, 38) and said control of intake air through said variable air intake means (27, 28) are performed in at least said specified engine operating zone.

Patentansprüche

1. Saugluftsteuerungssystem für einen mit einem Abgasrückführungssystem (35) versehenen Motor zur Durchführung der Steuerung von Mitteln zur Abgasregelung (36, 37, 38), welches Saugluftsteuerungssystem Mittel zur Detektierung von Motorbetriebsbedingungen (41, 42, 43, 44, 45, 46) für das Detektieren eines Motorbetriebszustandes aufweist, welcher mindestens eine Motordrehzahl (Ne), eine Drosselklappenventilöffnung (Tvo), eine Ansauglufttemperatur (Tha), eine Menge an Ansaugluft (Afs), eine Gaspedalstellung (Acc) und einen atmosphärischen Druck (Atp) umfaßt, wobei das Saugluftsteuerungssystem des weiteren Mittel zur Bestimmung der Solldrosselklappenventilöffnung (50, 57) für die Bestimmung einer Sollventilöffnung (Tvoob) eines Drosselklappenventils (28) aufgrund des genannten Motorbetriebszustandes, Mittel zur Bestimmung einer Soll-AGR-Ventilöffnung (50, 68) für die Bestimmung eines Sollwertes der Ventilöffnung (Pegrob) eines AGR-Ventils (36) entsprechend dem genannten Motorbetriebszustand und Steuerungsmittel (50, 53) zur Steuerung von Mitteln für variable Luftansaugung aufweist, welche ein Drosselklappenventil (27, 28) für die Steuerung des genannten Drosselklappenventils (28) zur Annäherung an den genannten Sollwert der Ventilöffnung (Tvoob) und des genannten AGR-Ventils (36) zur Annäherung an den genannten Sollwert (Pegrob) umfassen, **dadurch gekennzeichnet, daß**
das genannte Mittel zur Bestimmung der Solldrosselklappenventilöffnung (50, 57) aufgrund der genannten detektierten Motordrehzahl (Ne) und der genannten detektierten Gaspedalstellung (Acc) eine Berechnung eines Sollwertes des vom Motor abgegebenen Drehmoments (Trqob) ausführt, aufgrund eines Kennfeldes, das Basisdrosselklappenventilöffnungen relativ zu Motordrehzahlen und zum Sollwert des vom Motor abgegebenen Dreh-

moments definiert, entsprechend der genannten Motordrehzahl (Ne) und dem genannten vom Motor abgegebenen Drehmoment (Trqob) eine Basisdrosselklappenventilöffnung (Tvob) bestimmt, aufgrund volumetrischer Effizienz, die entsprechend der genannten detektierten Motordrehzahl (Ne) und der genannten detektierten Drosselklappenventilöffnung (Tvo) aufgrund eines Kennfeldes bestimmt wird, das die volumetrische Effizienz relativ zu Motordrehzahlen und Drosselklappenventilöffnungen definiert, eine geschätzte Menge der Luftladung (Ceest) zur Berechnung einer Solldrosselklappenventilöffnung ermittelt, welche Menge entsprechend der genannten detektierten Ansauglufttemperatur (Tha) und dem genannten detektierten atmosphärischen Druck (Atp) korrigiert wird, welche Korrektur die Tendenz hat, die genannte geschätzte Menge der Luftladung relativ zu einer Sollmenge der Luftladung (Ceob) für die Berechnung einer Solldrosselklappenventilöffnung in dem Maße zu mindern, wie die genannte Ansauglufttemperatur sinkt, aufgrund eines Kennfeldes, welches die Sollmengen an Luftladung relativ zur Motordrehzahl und zum Sollwert des vom Motor abgegebenen Drehmoments definiert, entsprechend der genannten detektierten Motordrehzahl (Ne) und dem genannten Sollwert des vom Motor abgegebenen Drehmoments (Trqob) die genannte Sollmenge an Luftladung (Ceob) bestimmt und aufgrund eines Feedback-Korrekturwertes (Ctfb), welcher entsprechend einer Differenz zwischen der genannten geschätzten Menge der Luftladung (Ceest) und der genannten Sollmenge der Luftladung (Ceob) sowie der genannten Basisdrosselklappenventilöffnung (Tvob) ermittelt wird, die genannte Sollventilöffnung (Tvoob) des genannten Drosselklappenventils (28) berechnet; und dadurch, daß
das genannte Mittel zur Bestimmung der Soll-AGR-Ventilöffnung (50, 68) aufgrund eines Kennfeldes, welches Basis-AGR-Ventilöffnungen relativ zu Motordrehzahlen und zum Sollwert des vom Motor abgegebenen Drehmoments definiert, entsprechend der genannten detektierten Motordrehzahl (Ne) und dem genannten Sollwert des vom Motor abgegebenen Drehmoment (Trqob) eine Bestimmung einer Basis-AGR-Ventilöffnung (Pegrb) des genannten AGR-Ventils (36) ausführt, ferner aufgrund eines Kennfeldes, das die Sollmenge der Luftladung relativ zu Motordrehzahlen und zum Sollwert des vom Motor abgegebenen Drehmoments definiert, entsprechend der genannten detektierten Motordrehzahl (Ne) und dem genannten Sollwert des vom Motor abgegebenen Drehmoments (Trqob) die Bestimmung einer Sollmenge der Luftladung (Ceob) für die Berechnung einer AGR-Ventilöffnung ausführt, und des weiteren aufgrund der genannten Basisventilöffnung (Pegrb) des genannten AGR-Ventils (36) eine Berechnung des Sollwertes der genannten Ventilöffnung (Pegrob) des genannten AGR-Ventils (36) und eines Feedback-Korrekturwertes (Pegrfb) ausführt, welcher entsprechend einer Differenz zwischen der genannten Sollmenge der Luftladung (Ceob) und einer entsprechend der genannten detektierten Menge an Ansaugluft (Afs) berechneten Menge der Luftladung (Ce) ermittelt wird.

2. Saugluftsteuerungssystem nach Anspruch 1, **dadurch gekennzeichnet, daß** das genannte Steuerungsmittel (50, 53) die Steuerung der genannten Menge der Luftladung mit dem genannten Mittel für variable Luftansaugung (27, 28) durchführt, während das genannte Abgasrückführungssystem (35) die genannte Steuerung des genannten Mittels zur Abgasregelung (36, 37, 38) ausführt.

3. Saugluftsteuerungssystem nach Anspruch 1, **dadurch gekennzeichnet, daß** das genannte Mittel für variable Luftansaugung (27, 28) ein elektrisch betätigtes Drosselklappenventil aufweist.

4. Saugluftsteuerungssystem nach Anspruch 1, **dadurch gekennzeichnet, daß** die genannte Basisdrosselklappenventilöffnung und eine durch das genannte Mittel zur Abgasregelung (36, 37, 38) geregelte Abgasmenge so eingestellt werden, daß in einem Motorbetriebsbereich, in dem die genannte Steuerung des Mittels zur Abgasregelung (36, 37, 38) und die genannte Steuerung des genannten Mittels für variable Luftansaugung (27, 28) durchgeführt werden, der Druck in einem Ansaugluftkanal (24a) stromab vom genannten Mittel für variable Luftansaugung (27, 28) ungefähr auf die gleiche Höhe eingestellt wird, wie der atmosphärische Druck, soweit die genannte Basisdrosselklappenventilöffnung kleiner ist als die genannte vollständig geöffnete Stellung.

5. Saugluftsteuerungssystem nach Anspruch 1, **dadurch gekennzeichnet, daß** die genannte Drosselklappenventilöffnung nur dann in eine vollständig geöffnete Stellung gebracht wird, wenn die Ansaugluftdichte in einem Motorbetriebsbereich, in dem die genannte Steuerung des Mittels zur Abgasregelung (36, 37, 38) und die genannte Steuerung des genannten Mittels für variable Luftansaugung (27, 28) ausgeführt werden, gering ist und die genannte Basisdrosselklappenventilöffnung groß eingestellt wird.

6. Saugluftsteuerungssystem nach Anspruch 1, **dadurch gekennzeichnet, daß** der genannte Motor ein Motor mit Direkteinspritzung ist, welcher einen Kraftstoffinjektor (22) aufweist, der so gesteuert wird, daß er in einem Verdichtungshub derart Kraftstoff einspritzt, daß in einem vorgegebenen Motorbetriebsbereich ein geschichtetes Luft-/Kraftstoffgemisch geschaffen wird und daß die genannte Steuerung der Abgasrückführung durch das genannte Mittel zur Abgasregelung (36, 37, 38) und die genannte Steuerung der Ansaugluft durch das Mittel für variable Luftansaugung (27, 28) zumindest in dem genannten vorbestimmten Motorbetriebsbereich ausgeführt werden.

Revendications

1. Système de commande d'air d'admission pour un moteur équipé d'un système de recirculation des gaz d'échappement (35) destiné à effectuer la commande du moyen de réglage des gaz d'échappement (36, 37, 38), ledit système de commande d'air d'admission comportant un moyen de détection de l'état de fonctionnement du moteur (41, 42, 43, 44, 45, 46) destiné à détecter un état de fonctionnement du moteur comprenant au moins un régime moteur (Ne), une ouverture de papillon (Tvo), une température d'air d'admission (Tha), une quantité d'air d'admission (Afs), une ouverture d'accélérateur (Acc) et une pression atmosphérique (Atp), un moyen de détermination de l'ouverture de consigne du papillon (50, 57) pour déterminer une ouverture de consigne du clapet (Tvoob) d'un papillon (28) selon ledit état de fonctionnement du moteur, un moyen de détermination de l'ouverture de consigne d'une soupape EGR (50, 68) pour déterminer une ouverture de consigne du clapet (Pegrob) d'une soupape EGR (36) selon ledit état de fonctionnement du moteur, et un moyen de commande (50, 53) pour commander un moyen d'admission d'air variable incluant un papillon (27, 28) pour commander ledit papillon (28) vers ladite ouverture de consigne du clapet (Tvoob) et ladite soupape EGR (36) vers ladite ouverture de consigne du clapet (Pegrob), **caractérisé en ce que**
ledit moyen de détermination de l'ouverture du papillon (50, 57) effectue un calcul du couple moteur de sortie de consigne (Trqob) à partir dudit régime moteur (Ne) détecté et de ladite ouverture d'accélérateur (Acc) détectée, la détermination d'une ouverture de base du papillon (Tvob) selon ledit régime moteur (Ne) et ledit couple moteur de sortie de consigne (Trqob) à partir d'une cartographie définissant les ouvertures de papillon de base par rapport aux régimes moteur et au couple moteur de sortie de consigne, une estimation d'une quantité estimée de charge d'air (Ceest) pour le calcul d'une ouverture de consigne du papillon à partir du rendement volumétrique qui est déterminé d'après ledit régime moteur (Ne) détecté et ladite ouverture de papillon (Tvo) détectée à partir d'une cartographie définissant le rendement volumétrique par rapport aux régimes moteur et aux ouvertures de papillon, laquelle quantité étant ensuite soumise à une correction selon ladite température d'air d'admission (Tha) détectée et ladite pression atmosphérique (Atp) détectée qui a tendance à diminuer ladite quantité estimée de charge d'air par rapport à une quantité de consigne de charge d'air (Ceob) pour le calcul d'une ouverture de consigne du papillon dans la mesure où la température dudit air d'admission diminue, la détermination de ladite quantité de consigne de charge d'air (Ceob) selon ledit régime moteur (Ne) détecté et ledit couple moteur de sortie de consigne (Trqob) à partir d'une cartographie définissant des quantités désirées de charge d'air par rapport au régime moteur et au couple moteur de sortie de consigne, et un calcul de ladite ouverture de consigne du clapet (Tvoob) dudit papillon (28) à partir d'une valeur de correction de retour (Ctfb) qui est déterminée selon une différence entre ladite quantité estimée de charge d'air (Ceest) et ladite quantité de consigne de charge d'air (Ceob) ainsi que ladite ouverture de papillon de base (Tvob) ; et ledit moyen de détermination de l'ouverture de consigne de la soupape EGR (50, 68) effectue la détermination d'une ouverture de base de la soupape EGR (Pegrb) de ladite soupape EGR (36) selon ledit régime moteur (Ne) détecté et ledit couple moteur de sortie de consigne (Trqob) à partir d'une cartographie définissant des ouvertures de base de la soupape EGR par rapport aux régimes moteur et au couple moteur de sortie de consigne, la détermination d'une quantité de consigne de charge d'air (Ceob) pour le calcul d'une ouverture de soupape EGR selon ledit régime moteur (Ne) détecté et ledit couple moteur de sortie de consigne (Trqob) à partir d'une cartographie définissant les quantités désirées de charge d'air par rapport aux régimes moteur et au couple moteur de sortie de consigne, et un calcul de ladite ouverture de consigne du clapet (Pegrob) de ladite soupape EGR (36) à partir de ladite ouverture de base du clapet (Pegrb) de ladite soupape EGR (36) et une valeur de correction de retour (Pegrfb) qui est déterminée selon une différence entre ladite quantité de consigne de charge d'air (Ceob) et une quantité de charge d'air (Ce) calculée à partir de ladite quantité d'air d'admission (Afs) détectée.

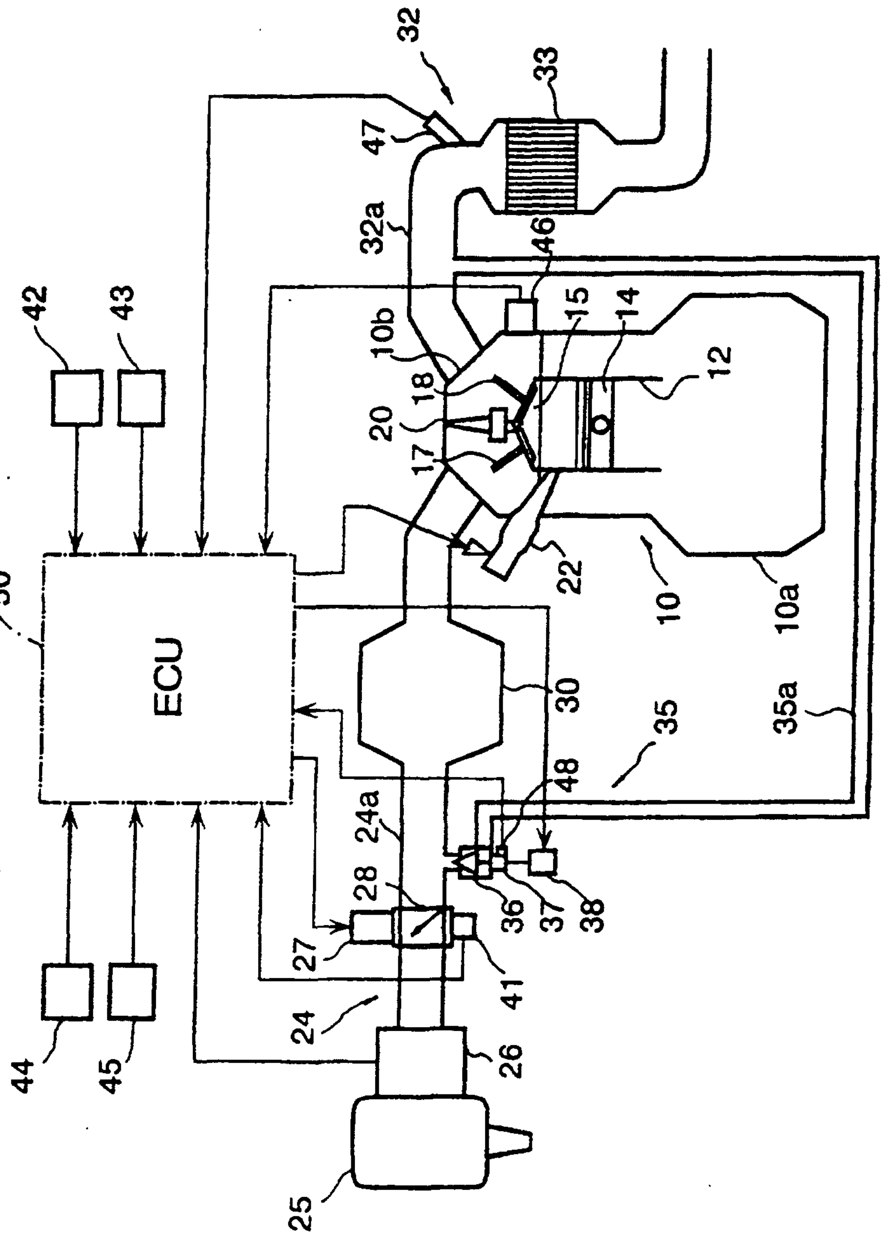
2. Système de commande d'air d'admission selon la revendication 1, **caractérisé en ce que** ledit moyen de commande (50, 53) effectue la commande de ladite quantité de charge d'air par l'intermédiaire du moyen d'admission d'air (27, 28) variable alors que le système de recirculation des gaz d'échappement (35) exécute ladite commande dudit moyen de réglage des gaz d'échappement (36, 37, 38).

3. Système de commande d'air d'admission selon la revendication 1, **caractérisé en ce que** ledit moyen d'admission d'air (27, 38) variable comporte un papillon actionné électriquement.

4. Système de commande d'air d'admission selon la revendication 1, **caractérisé en ce que** ladite ouverture de base du papillon et une quantité commandée dudit moyen de réglage des gaz d'échappement (36, 37, 38) sont réglées de sorte que la pression dans un passage d'air d'admission (24a) en aval du moyen d'admission d'air (27, 28) variable est amenée à être approximativement égale à la pression atmosphérique dans la mesure où l'ouverture de base du papillon est inférieure à ladite position d'ouverture entière dans une zone de fonctionnement du moteur dans laquelle ladite commande du moyen de réglage des gaz d'échappement (36, 37, 38) et la commande dudit moyen d'admission d'air (27, 28) variable sont effectuées.

5. Système de commande d'air d'admission selon la revendication 1, **caractérisé en ce que** ladite ouverture de papillon est réglée à une position d'ouverture entière seulement lorsque la densité de l'air d'amission est basse dans une zone de fonctionnement du moteur dans laquelle ladite commande du moyen de réglage des gaz d'échappement (36, 37, 38) et ladite commande dudit moyen d'admission d'air (27, 28) variable sont effectuées et ladite ouverture de base du papillon est réglée pour être grande.

6. Système de commande d'air d'admission selon la revendication 1, **caractérisé en ce que** ledit moteur est du type à injection directe de carburant, présentant un injecteur de carburant (22) qui est commandé pour injecter du carburant dans un temps de compression pour créer un mélange d'air/carburant stratifié dans une zone de fonctionnement du moteur spécifique et ladite commande de la recirculation des gaz d'échappement par ledit moyen de réglage des gaz d'échappement (36, 37, 38) et ladite commande d'admission d'air par ledit moyen d'admission d'air (27, 28) variable sont effectuées au moins dans ladite zone de fonctionnement du moteur spécifique.


ECU
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33
47
32a
46
10b
15
14
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12
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17
22
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10a
30
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35a
48
24a
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36
37
38
27
41
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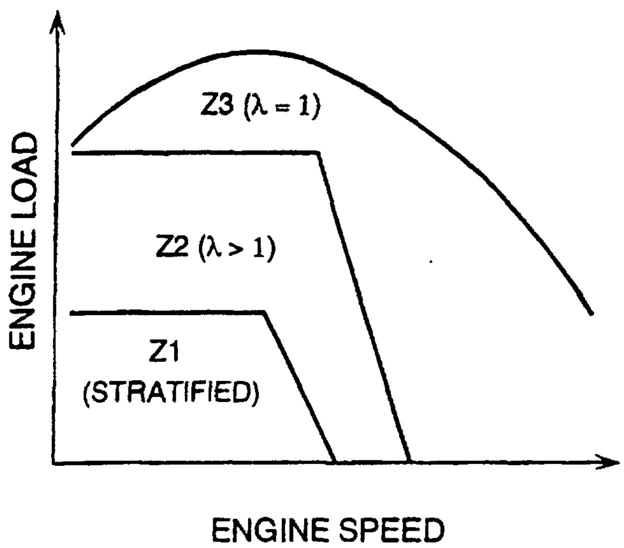
FIG. 1

FIG. 2



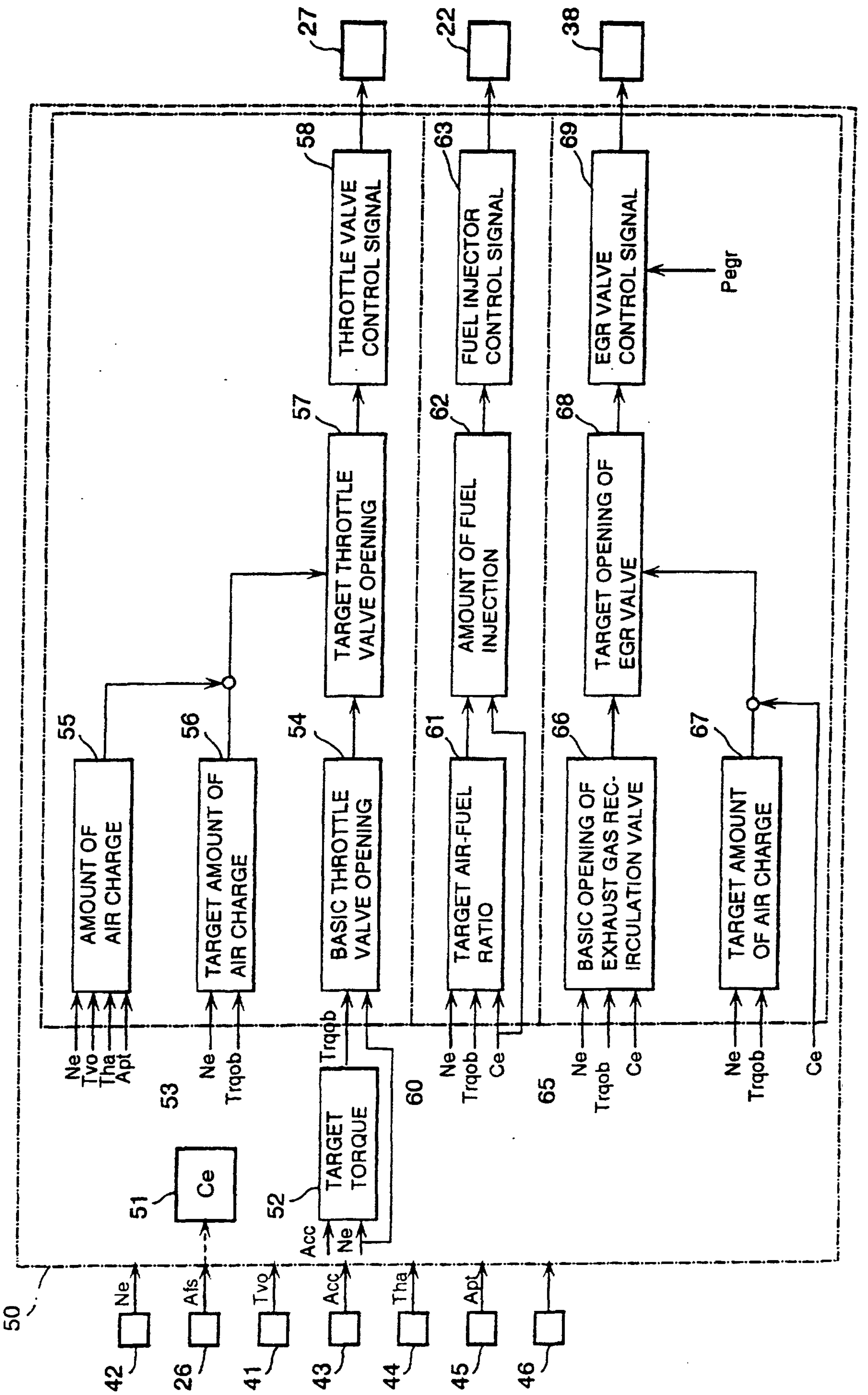

THROTTLE VALVE CONTROL SIGNAL
FUEL INJECTOR CONTROL SIGNAL
EGR VALVE CONTROL SIGNAL
Pegr
TARGET THROTTLE VALVE OPENING
AMOUNT OF FUEL INJECTION
TARGET OPENING OF EGR VALVE
AMOUNT OF AIR CHARGE
TARGET AMOUNT OF AIR CHARGE
BASIC THROTTLE VALVE OPENING
TARGET AIR-FUEL RATIO
BASIC OPENING OF EXHAUST GAS REC-IRCULATION VALVE
TARGET AMOUNT OF AIR CHARGE
TARGET TORQUE
Ce
Ne
Tvo
Tha
Apt
Trqob
Acc
Afs
27
22
38
58
63
69
57
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FIG. 3

FIG. 4

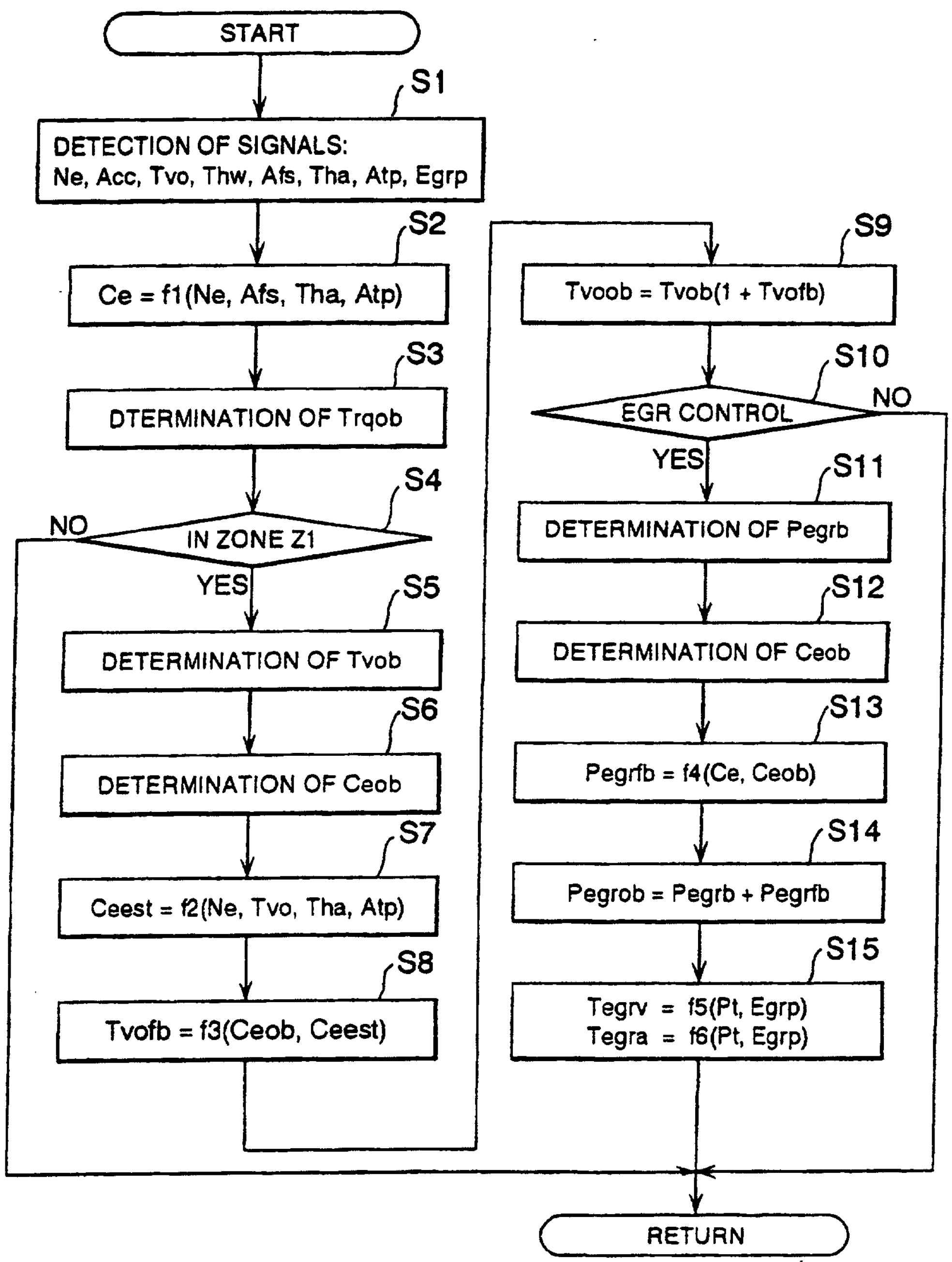
START
S1
DETECTION OF SIGNALS:
Ne, Acc, Tvo, Thw, Afs, Tha, Atp, Egrp
S2
Ce = f1(Ne, Afs, Tha, Atp)
S3
DTERMINATION OF Trqob
S4
IN ZONE Z1
NO
YES
S5
DETERMINATION OF Tvob
S6
DETERMINATION OF Ceob
S7
Ceest = f2(Ne, Tvo, Tha, Atp)
S8
Tvofb = f3(Ceob, Ceest)
S9
Tvoob = Tvob(1 + Tvofb)
S10
EGR CONTROL
NO
YES
S11
DETERMINATION OF Pegrb
S12
DETERMINATION OF Ceob
S13
Pegrfb = f4(Ce, Ceob)
S14
Pegrob = Pegrb + Pegrfb
S15
Tegrv = f5(Pt, Egrp)
Tegra = f6(Pt, Egrp)
RETURN

FIG. 5A

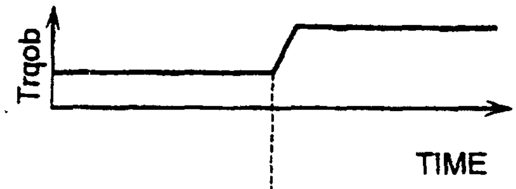

FIG. 5B

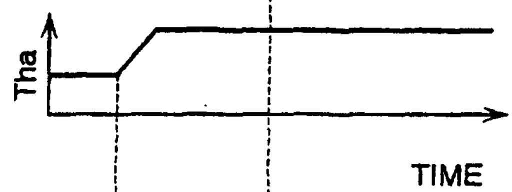

FIG. 5C

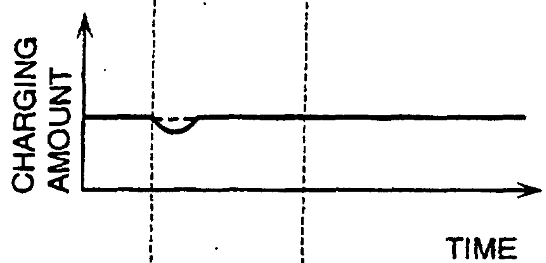

FIG. 5D

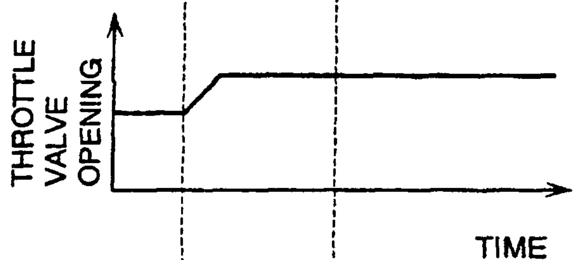

FIG. 5E

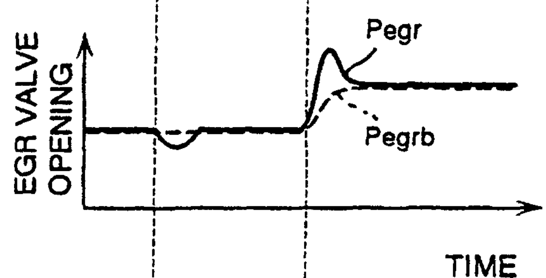

FIG. 5F